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AN ASSESSMENT OF EFFLUENT QUALITY AT A SMALL METAL FINISHING PLANT

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1.0 Introduction

Generators of small quantities of hazardous waste are often not aware of the availability of waste minimization technology. Furthermore, they often lack the capability to devise cost-effective waste management strategies.

A technical assistance program was developed in 1986 by Environmental Protection, Western and Northern Region of Environment Canada. It is directed at small industries, the first being metal finishing operations. Under this program companies may receive assistance through either a field assessment or audio-visual training courses.

The program focuses on "practical options" for reducing waste generation at source. It identifies and characterizes waste generation and provides recommendations for waste management alternatives to minimize waste generation at source through operational changes, process modifications, material substitution, waste exchange, and good housekeeping practices.

This report is a result of the effort of the technical assistance program aimed at assisting metal finishers to improve plant waste management at their plants. Special emphasis is placed on practical options for waste reduction at source.

2.0 Physical Description of Plant Plating Processes

This plant comprised a single plating line which included three metal plating processes: nickel, brass and chrome. The tanks on the line were large and of uniform size, design and construction, and used for small and large items (Figure 1).

Most rinsing water was obtained from an on-site well, and sometimes additional water was taken from the City of Winnipeg distribution system. Spent rinse water was discharged to the Winnipeg sewer system.

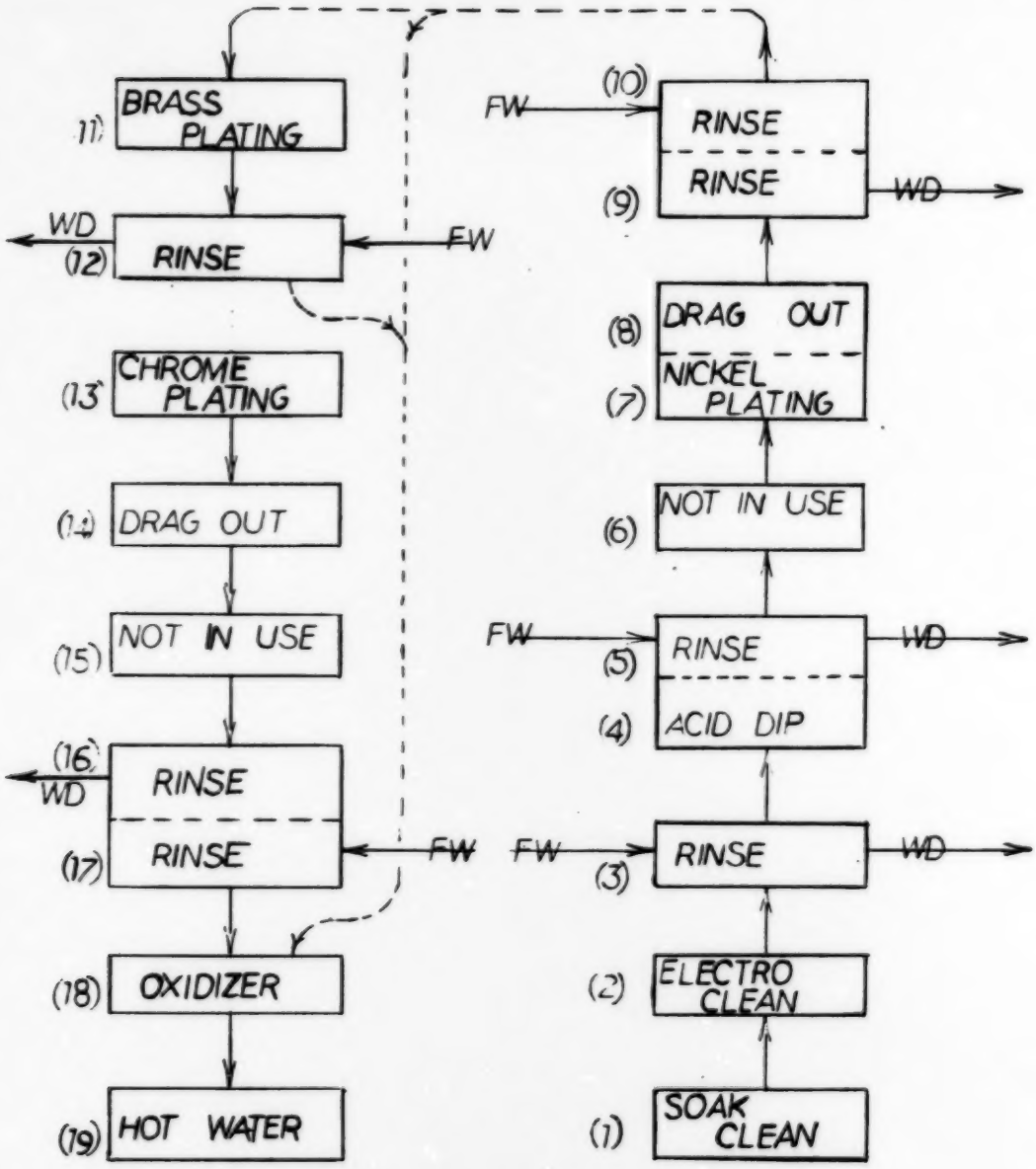

FIGURE 1. ARRANGEMENT OF PLATING LINE TREATMENT TANKS

This illustrates how the plating line was organized during December, 1986 when samples were collected. Arrows on the side of each tank indicate the direction pieces are moved through the system. Arrows at the "end" of tanks indicate the direction of the flow of rinse water.
FW= fresh water, WD= wastewater discharge.

3.0 Methods

3.1 Observation of Operating Procedures

Environmental Protection initially obtained a general description of the plant plating line and processes by interviewing plant management. This information was used to determine sampling and analytical requirements. On-site sampling, collection of data and detailed process information, were undertaken on one day, December 5, 1986.

When collecting plating line data at the plant the procedure followed was to first obtain a description, from the plant owner, of the plating line operations and also the contents of each tank. This information was used to determine analytical requirements for rinse water samples. Preliminary process diagrams were prepared and sampling locations were determined.

During the period of data collection the operator was observed to confirm the sequence of treatment and rinsing tanks used during plating, and to record some drag-out times. Tank dimensions and rinse tank temperatures were also recorded. The rinse tanks were observed to see if countercurrent rinsing was practiced, and the sources of the rinse water were also identified - well water or City of Winnipeg

water. The condition of all tanks and pipes on each plating line was observed to identify leakage but none was found.

3.2 Sampling of Rinse Tank Water and Plant Effluent

One grab sample of rinse water was taken from each rinse tank. During the sampling period both well water and City of Winnipeg water were flowing to the rinse tanks because the plating line was in active operation.

The composite sample of the final plant effluent was taken from a final effluent discharge hose which drained to the Winnipeg sewer system. This composite was collected between 08:30 and 16:00 hrs., during plating operations, at 20-minute sampling intervals.

All samples were refrigerated and shipped to the Environmental Protection Regional Laboratory in Edmonton where the analyses were conducted. No sample preservatives were used. The sampling directives in the federal Metal Finishing Effluent Guidelines (1) were followed.

The parameters determined for rinse water effluents were: pH, conductivity, total chromium, copper, total cyanide, iron, nickel and zinc. All parameters were determined for the composite sample, but not necessarily for each rinse water grab sample.

The pH measurements were made in the field using a Metrohm Unit pH meter, model number E588. The other analyses were conducted by the Environmental Protection Regional Laboratory in Edmonton. All analyses followed the procedures outlined in the "Standard Methods" manual (2).

3.3 Wastewater Flow Measurements

Fresh water was directed into individual rinse tanks from one of two hoses. One hose supplied water from an on-site well while the other was connected with the City of Winnipeg water system. Well water was used most frequently; City of Winnipeg water was used when the plating line was busy and required additional rinsing capacity. Both water supplies were being used during the sample collection on December 5, 1986. The supply hoses were placed in rinse tanks for an unspecified period, perhaps one-half hour to one hour, then moved to another rinse tank.

Rinse water flows were determined for each water source by recording the time required to fill a calibrated bucket. When measuring each flow rate at least three individual determinations were made for each rinse water source. The mean values were reported as the actual flow (Results; Table 2).

4.0 Results

4.1 Description of Plating Line

The plating line at this plant consisted of cleaning, plating, and rinse tanks of uniform size as illustrated in Figure 1. The tanks were arranged side-by-side in two rows. Sometimes a temporary treatment tank was added to permit other plating processes. There were no agitation or mixing devices in the rinse tanks.

Plating was conducted by dipping a rack with pieces attached into the process tanks using an overhead hoist. The hoist was mounted on a track and operated with compressed air. The operator on the plating line followed specific processing sequences for particular plating operations. The operator used considerable judgement in determining the times pieces remained in the process tanks. The operator also determined the time permitted for drag-out. During the sample collection day some drag-out times were recorded to determine their length. These data are given in Table 1.

TRANSFER FROM	TRANSFER TO	DRAINING TIMES (seconds)
Nickel plating	Nickel drag-out	9
Nickel drag-out	Nickel rinse	12.5
Acid dip	Acid dip rinse	38
Electroclean	Electroclean rinse	4

Table 1. Draining Times Used by Operator

These periods were single observations made on December 5, 1986 when samples were being collected.

4.2 Water Use and Waste Management Practices

4.2.1 General Observations

All tanks on the plating line were constructed of steel, but none of the tanks was leaking. Drainage pipes from some tanks were subject to corrosion but no leaks were observed in the pipes.

There were no drainage boards between adjacent tanks. There was limited protection from spillages and overflows when adding fresh water to process tanks to compensate for

evaporative and drag-out losses, or making up new solutions in the treatment tanks. It is also possible that some chemical spillages could have occurred when reagents were being added to existing solutions or when new solutions were being prepared. There were no special storage facilities for plating and cleaning chemicals, however, only small amounts of these materials were kept on-site.

4.2.2 Water Use

The ground water used for most rinsing operations was pumped from an on-site well and directed to the rinse tanks through a hose (approximately 3/4 inch in internal diameter). City of Winnipeg water was sometimes used when additional rinsing capacity was required. Water was turned on at the commencement of plating operations and continued to flow during the plating period. The fresh water hose was transferred from rinse tank to rinse tank by the operator. Water was introduced at approximately the mid-depth level of the rinse tanks. City of Winnipeg water was used for preparing treatment solutions and also as makeup water in processing tanks.

At rinsing stations with two compartments, that is compartments 9 and 10, and compartments 16 and 17 (Figure 1), counter-current rinsing was practiced. Fresh water from the hose entered the second compartment, then over-

flowed to the first rinse compartment. Wastewater from the first compartment was then drained by pipe to the municipal sewer system.

There were no flow control or flow measuring devices used to dispense rinse waters. There were no agitation or mixing devices used to promote rinsing. No water recycling systems were in place.

4.2.3 Current Waste Management Practices

Spent rinse waters did not undergo treatment before entering the Winnipeg sewer system. Spent cleaning and plating solutions were discharged to the Winnipeg sewers without treatment, although the pH was monitored before discharge. There was no reclamation or removal of metals from discharge waters. There were no records of disposal of used solutions and sludges. Sludges have been disposed of, in the past, in City of Winnipeg landfills.

4.3 Waste Characterization

4.3.1 Water/Wastewater Flows

There was no metering equipment to measure water use at the plant. At the time of sampling the plant was in operation and both well water and city water were being

used for rinsing. The flows from each of the two water hoses were determined by recording the time required to fill a calibrated container (a five-gallon pail was used). The flow data are reported in Table 2. This represents the maximum water use during plating, however, the plant was operating at close to full capacity. It is not possible to provide an accurate determination of total water use because water is turned on and off as production dictates. When flow data were collected on December 5, 1986 well water and city water were used all day (eight hours) which was estimated to total 9,232 litres and 11,280 litres for the respective sources.

Water Source	Flow Rate L/Min	Daily Rate of Flow L/Day (8 hr)
On-site Well Water (from 1/2 inch hose)	19.2	9,232
City of Winnipeg Water (from 1/2 inch hose)	23.2	11,280
Total Maximum Flows	**42.4**	**20,512**

(Flow Rate: 4,512 IGPD)

Table 2. Rinse Water Flows

Rinse water flows to the rinse tanks only when metal finishing is taking place. These data represent the approximate maximum use during an eight hour period when the plant was operating at close to full capacity. This was determined December 5, 1986.

4.3.2 Wastewater Quality Data

The data for the composite sample of final plant effluent collected on December 5, 1986 are reported in Table 3. The pH is slightly alkaline and the conductivity value is reflective of the well water in addition to the cleaning and plating constituents in the wastewater.

Date 1986	pH	Conductivity umho/cm	Total-CN mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Ni mg/L	Zn mg/L
Dec. 05	7.7	1708	0.04	0.10	0.13	0.65	16.3	0.104

Table 3. Final Effluent Quality Data

These data were obtained from composite samples of effluent collected during plant operation from the effluent discharge to the Winnipeg sewer system.

5.0 Discussion

5.1 Regulatory Requirements

In Manitoba there has been virtually no regulation of the metal finishing industry. During 1988 the City of Winnipeg established limits for several metals in its Sewer Utility By-law. These limits and the federal guideline limits for metals and other substances are listed in Table 4. The City of Winnipeg limits could be applied to any industries which discharge to the sewer system. As a result of the new Manitoba Environment Act responsibility for regulating the metal finishing industry may eventually be shifted to the Province.

The City of Winnipeg no longer permits the disposal of sludge from metal finishing plants at its waste disposal sites. There are no data available on the sludge disposal practices followed by metal finishers in Winnipeg. In 1988 the Manitoba Dangerous Goods Handling and Transportation Act required each generator of hazardous waste in the Province to obtain a licence; this will likely include sludge disposal by metal finishers. Manitoba intends to work with industrial waste generators to identify their specific and individual needs and have these addressed by the Manitoba Hazardous Waste Management Corporation.

Substance	Federal Guideline Limit mg/L	Winnipeg Sewer Utility By-law Limits mg/L
1. Aluminum	No Limit	50.0
2. Cadmium	1.5	2.0
3. Chromium (Total)	1.0	15.0
4. Chromium (Hexavalent)	Not Applicable	5.0
5. Copper	1.0	5.0
6. Lead	1.5	2.0
7. Mercury	No Limit	0.1
8. Nickel	2.0	5.0
9. Zinc	2.0	5.0
10. Cyanide (Oxidizable)	0.1	2.0
11. Cyanide (Total)	3.0	10.0
12. Total Suspended Matter	30.0	No Limit

Table 4. **Comparison of Federal Guideline Limits and Winnipeg Sewer Utility By-law Limits**

Comparison of limits for substances discharged in the federal "Metal Finishing Liquid Effluent Guidelines" (1) and the City of Winnipeg Sewer Utility By-law. The pH range in the Guideline is 6.0 to 9.5; in the By-law the range is 5.5 to 9.0.

During 1982 and 1983 Environment Canada conducted an inventory of metal finishing operations in Manitoba, which were described as "medium sized to very small". At that time all known plants discharged untreated effluents to municipal sewer systems.

The Government of Canada issued "Metal Finishing Liquid Effluent Guidelines" (1) in 1977 under the authority of the Minister of Fisheries and the Environment, which apply to every metal finishing plant. The substances and parameters considered for the purposes of the Guidelines include:

(a)	Total suspended matter	(f)	Cyanide (Total)
(b)	Cadmium	(g)	Lead
(c)	Chromium (Total)	(h)	Nickel
(d)	Copper	(i)	Zinc
(e)	Cyanide (Oxidizable)	(j)	pH

The federal guidelines are national baseline standards which are considered achievable through the implementation of "best practicable technology" (that is, technology which is both technically and economically viable). While a guideline is not enforceable it does indicate what practices are considered acceptable with respect to the intent of a particular act of Parliament; in this case, with respect to the Fisheries Act.

The federal guidelines provide objective concentrations for various substances and for pH in the final effluent from metal finishing plants; they provide a format for reporting concentrations of substances in effluent; and they provide reporting formats when disposing of spent processing solutions, sludges and residues.

5.2 Code of Good Housekeeping Practice

The federal guidelines manual (1) includes a "Code of Good Housekeeping Practice for the Metal Finishing Industry". It is described as supplemental to the guidelines and "was prepared to indicate methods and practices which should be followed to assist in meeting the requirements of the guidelines". The Code states, "conscientious supervision is the most important single factor in effecting good housekeeping practices".

Substitutes can be obtained for some toxic chemicals used in metal finishing. The Code (1) identifies several ways applicable to this study in which plant operators may reduce the release of contaminants:

1. "Cleaners containing non-biodegradable compounds should be completely avoided.
2. "The use of phosphates should be eliminated, if possible, or at least reduced to the lowest possible concentration.

3. "An effort should be made to replace environmentally dangerous chemicals with those less toxic or more readily removed from the effluent stream.

4. Wherever possible baths should be operated at the lowest concentration practicable."

The Code (1) states that plant operators are in the best position to determine rinsing needs and this can be done empirically by metal finishers themselves. Once a sufficient flow is established for a specific rinse tank, flow restrictors can be installed. None of the plating lines have any devices to enhance rinsing efficiency. The Code outlines several things which could be considered for each plating line:

1. Agitation of work while in the rinse tank;
2. Air agitation of the rinse water;
3. Hydraulic agitation of the rinse water;
4. Mechanical agitation of the rinse water with mixers or impellers;
5. Ultrasonic agitation of the rinse water;
6. Raising the water temperature;
7. Use of wetting agents; and
8. Introduction of fresh water at the bottom of the rinse tanks, using a spreader wherever possible.

5.3 Recommendations

Based on the foregoing information and assessments we make the following recommendations for operational and process changes. These recommendations deal with optimization of water use, and a reduction in the generation of toxic

waste through efficient use and containment of cleaning and process chemicals. We recommend a two-phase strategy for improvement of waste management. This constitutes Phase I in reducing the release into the environment of toxic materials associated with metal finishing. Phase II would involve end-of-pipe treatment of effluents from waste streams to recycle or remove toxic materials before discharge from the plant. Phase II should be regarded as a last resort after every attempt has been made to reduce waste generation. Phase I provides the best measure to minimize the cost of end-of-pipe treatment and the associated expense of hazardous waste disposal.

5.3.1 Phase I

The scope of Phase I includes action taken by the generator to modify plating processes or operational procedures to reduce the waste volume generated before end-of-pipe treatment and disposal, and replacement of hazardous raw materials with less or non-hazardous ones to reduce the degree of hazards of wastes.

Rationales for some of the recommendations have been described immediately following the corresponding recommendations.

5.3.1.1 Plating Line

Recommendation 1

Recycle nickel rinse (Tank 9) back into acid dip rinse (Tank 5); shut off fresh water feed to Tank 5 (Figure 2).

This would allow an opportunity of dragging back, partially, the plating solution previously dragged out of the plating bath. This would not harm the plating process.

Recommendation 2

Recycle acid dip rinse back to electro-clean rinse (Tank 3); turn off fresh water feed to electro-clean rinse (Tank 3) (Figure 2).

This will not only help to neutralize the alkaline clean rinse, but also enhance the rinsing efficiency of the alkaline clean rinse. In addition, by partially neutralizing the rinse water being dragged into the acid dip tank, it will practically increase the service life of the acid dip solution.

Recommendation 3

Use Tank 15 as a second drag-out tank for the chrome plating bath, and Tank 8, as a second drag-out for the nickel plating bath (Figures 2 and 3).

The greater the number of drag-out tanks used, the lower the contaminant concentrations in the running rinse.

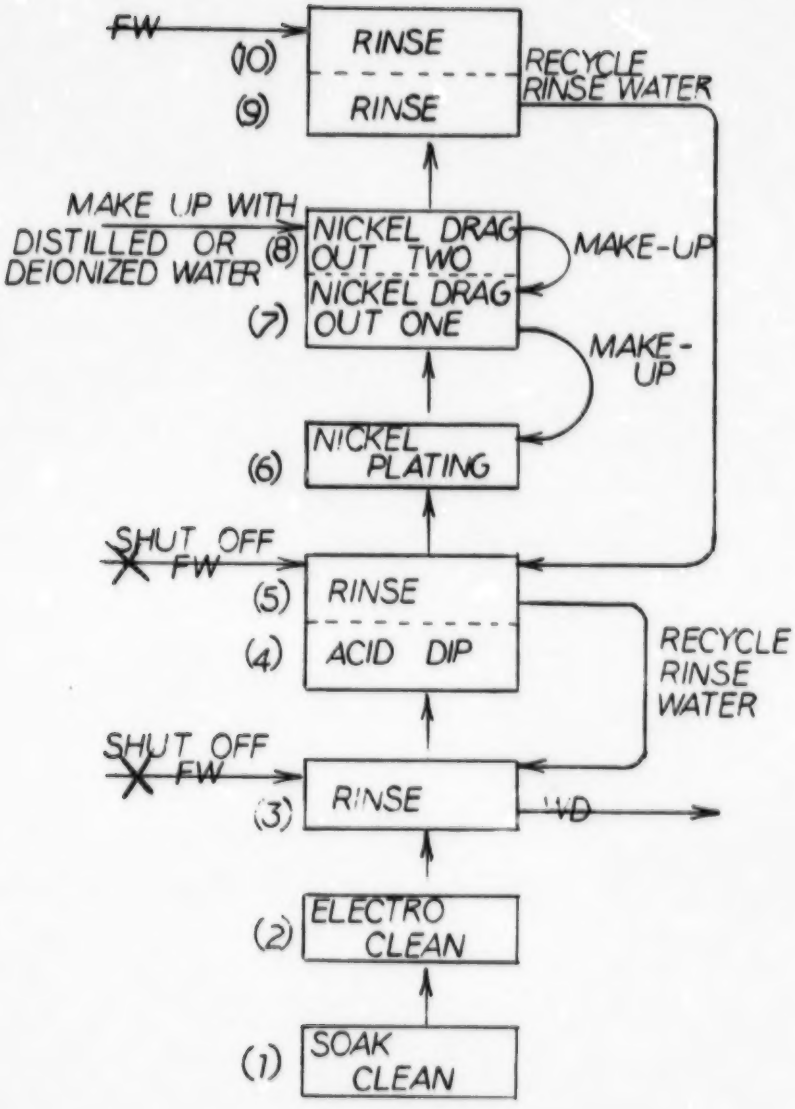

FIGURE 2. CHANGES TO PLATING LINE - 1

Tank 6 upgraded to be used as nickel bath; tank 7 becomes first nickel drag-out; tank 8 becomes second nickel drag-out. FW= fresh water, WD= wastewater disharge.

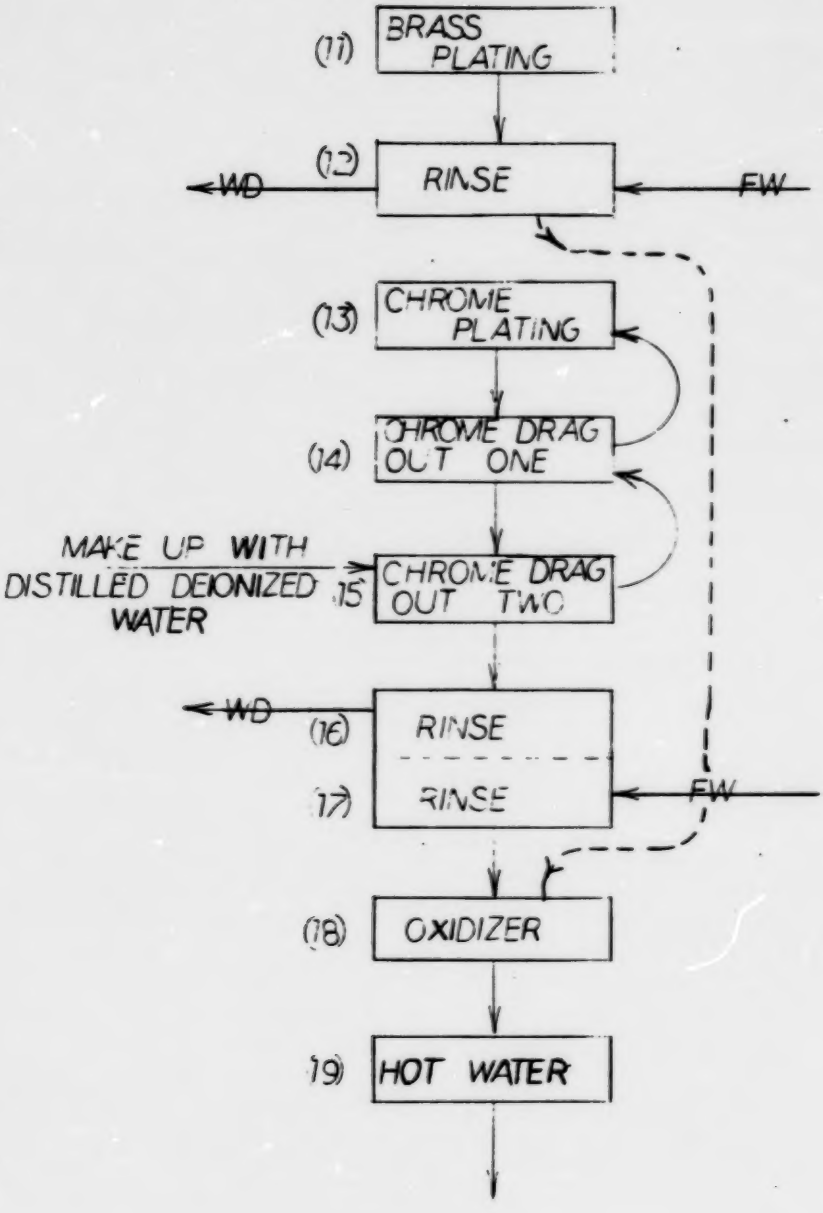

FIGURE 3. CHANGES TO PLATING LINE - 2

Tank 15 upgraded to used as second chrome drag-out.
FW= fresh water, WD= wastewater discharge.

Recommendation 4

Make up the plating bath evaporation from the first drag-out tanks; do not add fresh tap water or ground water to the plating baths.

A substantial amount of water loss will result due to evaporation from the heated nickel and chrome baths (Tanks 6 and 13 respectively). Returning the drag-out back to its corresponding plating bath will not only replace the evaporative losses, but will reduce the generation rate of hazardous wastes (Figures 2 and 3).

Recommendation 5

Recycle some of the liquid from the second drag-out tanks (Tanks 8 and 15) to the first drag-out tanks (Tanks 7 and 14 respectively); use distilled or deionized water to make up the second drag-out tanks (Figures 2 and 3).

The quality of water used to prepare bath solutions is of great importance in plating processes. It has been shown that some impurities in tap water may harm finishing processes (Table 5). Thus, if tap water or ground water is used to make up evaporative losses or to formulate bath solutions, water impurities will increase with time resulting in frequent dumping of bath solutions.

Ion	Finishing Process Affected
Chloride	Cr, Zn, Cu, Pb plating; anodizing
Calcium	Anodizing
Copper	Cr, Ni, Ni-Fe plating
Iron	Cr, Ni, Ag plating
Nitrate	Cd, Ni plating
Silica	Painting, general cleaning
Sulfate	Cr, Pb plating

Table 5. Tap Water Impurities vs Finishing Processes (Hankebo (3)

Recommendation 6

Decrease the temperature in the soak clean tank (Tank 1) from 70 to 50°C, and use a low temperature alkaline cleaner instead of the high temperature one.

The low temperature alkaline cleaner offers the following advantages (Jansen and Tervoort, (4)):

1) it will reduce the heating energy cost between 40 and 50 percent, and
2) the cost of cleaner chemicals and the generation rate of wastewater will be reduced due to the prolongation of the cleaner lifetime.

5.3.1.2 General Recommendations

Recommendation 1

Clean and remove the sediment from rinse tanks.

Good housekeeping is conducive to quality rinsing, and will reduce the generation of wastewater.

Recommendation 2

Introduce fresh water feed into the bottoms of rinsing tank through a submerged perforated distribution pipe or diffuser for each tank.

Recommendation 3

Install flow rate controllers on all rinse tanks with fresh water feed.

Recommendation 4

Use air agitation in all rinse tanks.

Air agitation is simple, inexpensive and efficient for inducing agitation in a rinse tank. The system consists of an air distribution line and an air

consists of an air distribution line and an air blower or compressor. Air is introduced through a perforated pipe into the bottom of a tank. A PVC (1/2" or 1 inch) pipe with one end capped can be used for distributing air (Figure 4) by drilling small holes on about 4 inch staggered centers.

The hole size may be from 3/32" to 1/8". To ensure even distrubiton of air, the cross-sectional area of the pipe should be greater than the combined area of all holes.

It is recommended that an air filter be used in conjunction with an air supplier to prevent atmospheric dust from getting into the rinse tank. A blower is preferred over a compressor to supply air, because the latter is considered to be impractical due to the high probability of introducing oil vapors into the agitated tank. Place the blower on a slotted platform well off the wet floor.

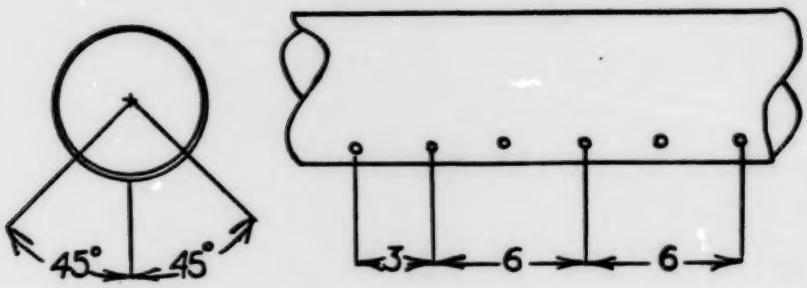

FIGURE 4. TYPICAL DRILLING OF AIR AGITATION SPARGER
(Mooney (5))

Recommendation 5

In addition to installing an air agitation system, rinsing efficiency can be improved by lifting plating racks momentarily out of the rinse tanks, allowing them to drain, and re-immersing them instead of leaving them immersed.

Recommendation 6

Minimize drag-out by holding workpieces over a plating tank for sufficient time to allow maximum drainage before transfer.

Care exercised by the operator is very important in reducing drag-out. Installing a hoist delay timer in the manual hoist line will help provide a time delay needed for adequate draining.

Recommendation 7

Select the lowest possible metal concentration at which the plating bath can be operated.

The lower the concentration of a bath solution, the lower its viscosity. The lower viscosity will result in a reduction in drag-out volume. Thus, decreasing a bath concentration will reduce not only the drag-out volume, but also the metal concentration of drag-out.

For example, a chromium plating bath may operate at a concentration of 25 oz/gal chromic acid. By using 25 instead of 30 oz/gal which is currently employed by the plant, a 17 percent decrease in drag-out concentration can be realized.

Recommendation 8

Maintain chrome and nickel baths at elevated temperatures during non-normal operating hours to induce additional evaporation.

This technique involves no capital investment except some expenditure of energy. It provides additional room for recycling valuable chemicals from drag-out tanks back to plating baths.

Recommendation 9

Attend waste management training programs designed for the metal finishing industry to make sure that good management practices are understood and exercised.

5.4 Impact of Waste Reduction Following Phase I Implementation

There is limited control on the delivery of fresh water to the individual rinsing tanks; the rinse tanks are not each provided with water pipes or hoses which can be separately turned on and off. Moving the water supply hose from tank to tank permits the plating line operator to change water only in the tanks being used, but this does not provide a predetermined minimum flow based on actual need.

Flows can be increased during heavy plating operations by using city water in addition to well water. This, however, does not provide the most effective control of water use. On the basis of the data obtained from the composite

sampling analyses (Table 3) it is likely that excessive water use is occurring frequently. By recycling water as described in the recommendations, and determining actual water requirements it is expected that significant efficiencies in water use would occur.

There are no standards for limiting water use in the federal metal finishing guidelines or the proposed changes to the City of Winnipeg sewer by-law. Simply regulating the concentrations of toxic materials in metal finishing effluents effectively encourages operators to meet concentation limits by diluting wastewater, especially when water is relatively inexpensive. This does not provide an incentive to reduce toxic materials entering wastewaters and sludges. Implementation of water and waste management practices may result, at least temporarily, in higher concentrations of toxic materials in wastewater. Some allowances for this may be necessary when process changes are being implemented. In such instances toxics concentrations in effluents may be higher but total loading should decrease. If the recommended process changes are introduced and waste concentrations in rinse water and drag-out tanks are maximized, then introduction of pollution control equipment, emphasizing recovery of metals and removal of toxics from plant effluents, can be implemented more economically. Otherwise, larger volumes of highly diluted toxics will continue to be released.

The benefits to the company of implementing a Phase I program include savings on raw materials resulting from minimization of drag-out, enhancement of rinsing efficiency, and a probable reduction in the rejection of plated parts.

If a 50 percent reduction in fresh rinse water use can be achieved, without a concomitant reduction in the release of toxic materials, it would theoretically result in a doubling of their concentrations in the plant effluent. If the average concentrations of toxics reported in Table 3 were each doubled most of them would still be within the limits the City of Winnipeg has established (Tables 4 and 6). Nickel was well above the by-law limit on December 5, 1986 and would likely continue to increase as water conservation measures are introduced. Because of the release of high concentrations of nickel in the single composite sample taken it would be prudent to confirm this result with additional sampling, to determine methods of conserving it during plating operations, and to implement measures for recovery.

Substance	Winnipeg Utility Sewer By-law Limit mg/L	Concentration in Composite Sample Taken December 5/86 mg/L	Theoretical Concentration Following 50% Reduction in Water Use mg/L
Chromium (Total)	15.0	0.1	0.2
Copper	5.0	0.13	0.26
Zinc	5.0	0.109	0.218
Nickel	5.0	16.3	32.6

Table 6. **Theoretical Projections for Concentrations of Toxic Materials Assuming a Fifty Percent Reduction in Water Use**

This table projects what the average effluent concentration of some toxic substances could be if a fifty percent reduction in water use was achieved without a concomitant reduction in the release of process materials. Nickel is the only substance, for which data were collected, that exceeds the City of Winnipeg Sewer Utility By-law limits for metal finishing toxics. The projections are based on data reported in Table 3.

6.0 Summary and Conclusions

In Winnipeg, metal finishing plant wastewater effluent discharges may be regulated by the City of Winnipeg and the Province of Manitoba.

A two-phase strategy has been recommended to improve waste management at the plant. The present study outlines Phase I which deals with the volume and concentration of wastes resulting from reuse of rinse water, air agitation, operational changes, material substitution and good housekeeping practices. Most recommendations could be implemented easily without the need of any sophisticated equipment. Preliminary data show that the waste volume may be reduced if Phase I recommendations are implemented. The projected concentrations of toxics in the final plant effluent are within the Winnipeg Sewer Utility By-law limits, except those for nickel.

Phase II involves end-of-pipe treatment and disposal, which could be implemented if regulatory pretreatment is required, but this is not within the scope of the present study.

It is suggested that a pollution reduction plan be developed by the company to control toxic materials in the

wastewater effluents. This would include equipment requirements and an implementation schedule.

7.0 References

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